Proton polarization in photo-excited aromatic molecule at room temperature enhanced by intense optical source and temperature control[†]

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For the study of unstable nuclei with polarization observables, we have constructed a solid polarized proton target[1)] based on the electron polarization in photo-excited aromatic molecules. Proton polarization of about 20 percent has been obtained at a temperature of 100 K, which is much higher than that under conventional conditions. The target has been successfully applied to several RI-beam experiments[2)] carried out at intermediate energies of several tens to a few hundred MeV/nucleon. One of the future directions of this research is conducting experiments at low energies of several to a few tens of MeV/nucleon. This will open up new possibilities such as resonant scattering and polarization transfer to embedded RIs. For such applications, the target should be placed in a vacuum environment and be polarized at room temperature. In our previous measurement at room temperature, a polarization of 4.8±1.2% was achieved by using *p*-terphenyl as the material. The aim of the present work is to investigate the possibility of achieving a high proton polarization of 30 percent for application to scattering experiments.

The magnitude of the polarization is expressed as $P_p = A\overline{P_e}/(A+\Gamma)$. Here, $\overline{P_e}$ is the electron polarization, A is the build-up rate, and Γ is the relaxation rate. In order to achieve a high polarization, we need to increase A and $\overline{P_e}$ or decrease Γ. To enhance the build-up rate A, we should increase the laser power for photo-excitation. However, in Iinuma *et al.*[3)] reported that a high laser power does not necessarily lead to a high polarization. This is considered to be because of the temperature rise of the sample. At temperatures higher than 300 K, the intrinsic relaxation rate Γ_{int} rapidly increases[4)] because of the molecular motion. Thus, it is expected that the polarization can be enhanced by using an intense optical source with the sample temperature controlled at $T \sim 300$ K.

The sample used in the present work is a single crystal of *p*-terphenyl doped with pentacene molecules with a concentration of 0.005 mol%. The target temperature was monitored with a platinum resistance thermometer. The temperature of the crystal was controlled by flowing cold N_2 gas. For the light source, we used an Ar ion laser with a wavelength of 514 nm.

The polarization was measured under two different conditions. The first condition (averaged laser power of 80 mW, w/o temperature control) is the same as that used in our previous measurement, where a polarization of 4.8% was achieved. The other condition (1.5 W, w/ temp. control), referred to as "present," was also considered. The time evolution of the polarization is shown in Fig. 1. In the present condition, the polarization is enhanced by a factor of three as compared with the polarization under the first condition. Although the absolute measurement is to be done in the future, the magnitude of achieved polarization corresponds to about 15% if we assume the polarization of 4.8% in the previous condition.

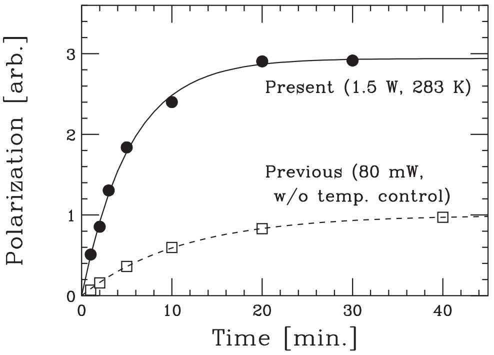

Fig. 1. Time evolution of proton polarization.

Finally, it should be mentioned that optimization of the time structure of the laser pulse would enhance the polarization rate $A\overline{P_e}$ by a factor of ∼5 *without* increasing the relaxation rate Γ (see Ref.[5)]). Thus, such optimization would almost directly improve the magnitude of polarization. Room-temperature polarization of 30 percent would be realized by combining a high power laser with a wavelength of ∼590 nm, through optimization of laser pulse structure, and employing a sophisticated temperature control system.

References

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